PHYSICS

Chapter 1

Measurements

Physics is the branch of science that deals with the study of nature and its laws

- **Physical quantity:** *All the quantities in terms of which laws of physics are described and which can be measured directly or indirectly are called* ***physical quantities****.* For example mass, length, time, speed, force etc. There are two types of physical quantities

(i) **Fundamental quantities :** The physical quantities which do not depend upon other physical quantities are called **fundamental** or **base physical quantities.** e.g. mass, length, time temperature electric current, luminous intensity and amount of substance.

(ii) **Derived quantities :** The physical quantities which depend on fundamental quantities are called **derived quantities** e.g. speed, acceleration, force, etc.

- **Unit:** The process of measurement is a *comparison process*. Unit is the standard quantity used for comparision.

  The chosen standard for measurement of a physical quantity, which has the same nature as that of the quantity is called the unit of that quantity.

  Every measured quantity (its magnitude) comprises of a number and a unit. **Ex:** In the measurement of time, say

  15 s
  ↙ ↘
  Number (n) Unit (u)

If Q is the **magnitude** of the quantity (which does not depend on the selection of unit) then

$$Q = n\,u = n_1\,u_1 = n_2\,u_2 \Rightarrow n \propto \frac{1}{u}$$

Where u_1 and u_2 are the units and n_1 and n_2 are the numerical values in two different system of units.

- **Fundamental (or Base) and Derived Units**

Fundamental units are those, which are independent of unit of other physical quantity and cannot be further resolved into any other units or the units of fundamental physical quantities are called **fundamental or base units.** e.g., kilogram, metre, second etc,

All units other than fundamental are derived units (**which are dependent on fundamental units**) e.g., unit of speed (ms^{-1}) which depends on unit of length (metre) and unit of time (second), unit of momentum ($Kgms^{-1}$) depends on unit of mass, length and time etc.

- *A* ***system of units*** *is a complete set of fundamental and derived units for all physical quantities.*
- **Different types of system of units**

F.P.S. (Foot - Pound - Second) system. (British engineering system of units.): In this system the unit of length is foot, mass is pound and time is second.

C.G.S. (Centimetre - Gram - Second) system. (Gaussian system of units): In this system the unit of length is centimetre, mass is gram and time is second.

M.K.S (Metre - Kilogram - Second) system. This system is related to mechanics only. In this system the unit of length is metre, mass is kilogram and time is second.

S.I. (International system) units: (Introduced in 1971) Different countries use different set of units. To avoid complexity, by international agreement, seven physical quantities have been chosen as fundamental or base physical quantities and two as supplementary. These quantities are

S.No	*Base physical quantity*	*Fundamental unit*	*Symbol*
1	Mass	kilogram	kg
2	Length	metre	m
3	Time	second	s
4	Temperature	kelvin	K
5	Electric current	ampere	A
6	Luminous intensity	candela	cd
7	Amount of substance	mole	mol

S.No	*Supplementary physical quantity*	*Supplementary unit*	*Symbol*
1	Plane angle	radian	rad
2	Solid angle	steradian	sr

Conventions of writing of Units and their Symbols

- Unit is **never written with capital initial letter.**
- For a **unit named after scientist the symbol is a capital letter** otherwise not.
- The unit or symbol is **never written in plural form.**
- **Punctuations marks are not written** after the symbol.
- **S.I. Prefixes :** The magnitudes of physical quantities vary over a wide range. For example, the atomic radius, is equal to 10^{-10}m, radius of earth is 6.4×10^{6} m and the mass of electron is 9.1×10^{-31} kg.

  The internationally recommended standard prefixes for certain powers of 10 are given in the table:

Prefix	*Power of 10*	*Symbol*
exa	18	E
peta	15	P
tera	12	T
giga	9	G
mega	6	M
kilo	3	k
hecto	2	h
deca	1	da
deci	–1	d
centi	–2	c
milli	–3	m
micro	–6	μ
nano	–9	n
pico	–12	p
femto	–15	f
atto	–18	a

- **Some Important Practical Units :**

(1) For large distance (macro-cosm)

Astronomical unit: It is the average distance of the centre of the sun from the centre of the earth. 1 A.U. = 1.496×10^{11}m

Light year: It is the distance travelled by the light in vacuum in one year. 1 *ly* = 9.46×10^{15}m

Parsec: One parsec is the distance at which an arc 1A.U. long subtends an angle of one second. 1 parsec = 3.1×10^{16}m

(2) For small distance (micro-cosm)

1 micron = 10^{-6}m 1nanometre = 10^{-9}m

1angstorm = 10^{-10}m 1fermi = 10^{-15}m

(3) For small area 1 barn = 10^{-28}m^2

(4) For heavy mass 1 ton = 1000kg

1quintal = 100kg 1slug = 14.57kg

1 C.S.L (chandrasekhar limit) = 1.4 times the mass of the sun

(5) For small mass 1 amu = 1.67 x 10^{-27}kg

1 pound = 453.6g = 0.4536 kg

(6) For small time 1 shake = 10^{-8}s

(7) For large time

Lunar month: It is the time taken by the earth to complete one rotation about its axis with respect to sun.

1L.M. = 27.3 days.

Solar day: It is the time taken by the earth to complete one rotation about its axis with respect to sun.

Sedrial day: It is the time taken by earth to complete one rotation on its axis with respect to distant star.

(8) For measuring pressure

1 bar = 1atm pressure = 10^5N/m^2 = 760mmHg

1torr = 1 mmHg

1 poiseuille = 10 Poise.

(9) For measuring temperature

$$\frac{T_C - 0}{100} = \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

Where T_C = tempereature in ^oC (degree Celsius)

T_F = tempereature in ^oF (degree Fahrenheit)

K = temperature in K (Kelvin)

Temperature difference in celsius scale is same as that in Kelvin scale.

At– 40^o temperature, the celsius and fahren reading are the same.

(10) For measuring energy

1 calorie = 4.2 joule

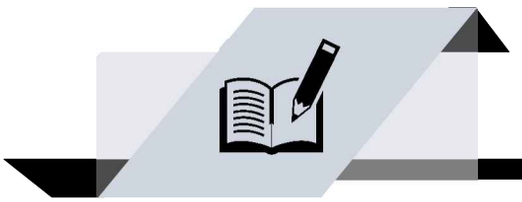
1 eV = 1.6×10^{-19} joule

- **S. I. Units of Some Important Physical Quantities :**

S.No.	*Physical quantity*	*Relation with other quantities*	*S.I. Unit*
1.	Velocity (v)	$\frac{\text{Length}}{\text{Time}}$	m/s
2.	Acceleration (a)	$\frac{\text{Velocity}}{\text{Time}}$	m/s^2
3.	Momentum (p)	Mass × velocity	kg-m/s
4.	Force (F)	Mass × acceleration	newton(N)
5.	Work	Force × displacement	Joule (J) = Ns
6.	Power (P)	$\frac{\text{Work}}{\text{Time}}$	watt (W) = J/s
7.	Universal gravitational constant (G)	$G = \frac{Fr^2}{m_1 m_2}$	N-m^2/kg^2
8.	Impulse	Force×time(F×t)	N-s
9.	Angular velocity (ω)	$\frac{\text{Angle}}{\text{Time}}\left(\frac{\theta}{t}\right)$	radian/s
10.	Angular Acceleration (α)	Angular velocity/time	radian/s^2
11.	Wavelength	Length	m
12.	Frequency	1/Time period	Hz
13.	Pressure (p)	$\frac{\text{force}}{\text{Area}}$	Pascal (Pa) = N/m^2
14.	Density (ρ)	$\frac{\text{mass}}{\text{volume}}$	kg/m^3
15.	Time period	$2\pi\sqrt{\text{length}}/g$	S
16.	Heat (θ)	Heat energy (Q)	joule (j)
17.	Specific Heat Capacity	$C = \frac{\theta}{m \times \Delta t}$	J/kg–K
18.	Heat Capacity	mass × specific heat	J/K
19.	Resistance (R)	$\frac{\text{Potential}}{\text{current}}\left(\frac{V}{I}\right)$	ohm(Ω)

20.	Conductance (c)	$\frac{1}{\text{Resistance}}$	mho (℧)
21.	Voltage, electric potential (V) or electromotive force (e.m.f.)	$\frac{\text{Work}}{\text{Charge}}\left(\frac{W}{q}\right)$	volt(v)
22.	Magnetic field($\vec{B}$)	$\frac{\text{Force}}{\text{Current} \times \text{length}}$	tesla (T)=Wb/m^2

23.	Power of lens	(Focal length)$^{-1}\left(\frac{1}{f}\right)$	dioptre (D)
24.	Refractive index (μ)	$\frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$	unitless
25.	Relative density	$\frac{\text{density of substance}}{\text{desnsity of water}}$	unitless

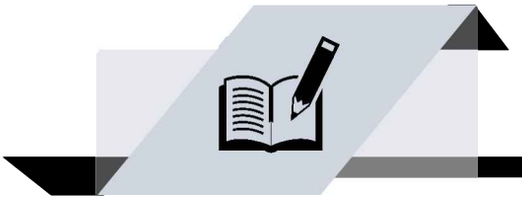


EXERCISE-1

1. Which one of the following is the smallest unit?
(1) millimetre (2) angstrom (3) fermi (4) metre
2. Which of the following systems of units is not based on units of mass, length and time alone ?
(1) SI (2) MKS (2) CGS (4) FPS
3. Number of base SI units is
(1) 4 (2) 7 (3) 3 (4) 5
4. Very large distances such as the distance of a Planet or a star from Earth can be measured by
(1) Spectrograph
(2) Millikan's oil drop method
(3) Parallax method
(4) All of these
5. Light year is
(1) light emitted by the sun in one year.
(2) time taken by light to travel from sun to earth.
(3) the distance travelled by light in free space in one year
(4) time taken by earth to go once around the sun.
6. Length cannot be measured by
(1) fermi (2) debye
(3) micron (4) light year
7. If the difference of temperature of two bodies is 5°C, then the difference of temperature on Kelvin scale is :
[Madhya Pradesh 2012]
(1) 268 K (2) 278 K (3) 5K (4) 54.6 K
8. Which of the following is not the unit of time ?
(1) Micro second (2) Leap year
(3) Lunar month (4) Parallactic second
9. Which of the following can measure length upto 10^{-5} m ?
(1) Metre scale (2) Vernier callipers
(3) Spherometer (4) None of these
10. Temperature can be expressed as derived quantity in terms of
(1) length and mass (2) mass and time
(3) length, mass and time (4) None of these
11. The bill of electric consumption is based on the measurement of **[JSTSE 2015]**
(1) current (2) voltage
(3) wattage (4) none of these
12. Unit of Relative Density is: **[JSTSE 2016]**
(1) kg/m^3 (2) kg/m^3
(3) kg/cm^3 (4) No unit
13. Vm^{-1} is the unit of **[West Bengal 2015]**
(1) Potential (2) Electric field intensity
(3) Electric current (4) Electric potential energy
14. Dyne-sec is the unit of
(1) momentum (2) force
(3) work (4) angular momentum
15. The SI unit of pressure is
(1) atmosphere (2) bar
(3) pascal (4) mm of Hg
16. Electron volt is a unit of
(1) potential difference (2) charge
(3) energy (4) capacity
17. Potential is measured in
(1) joule/coulomb (2) watt/coulomb
(3) newton-second (4) None of these
18. At what temperature will the Fahrenheit scale have the double reading as that of Celcius? **[West Bengal 2012]**
(1) 260 °C (2) 240°C (3) 160°C (4) 370°C
19. $N\ kg^{-1}$ is the unit of
(1) velocity (2) force
(3) acceleration (4) None of these
20. Which is not the unit of force? **[Rajasthan 2013]**
(1) poundal (2) dyne
(3) joule (4) newton
21. Which of the following pairs have same unit?
(1) Work and energy
(2) angular acceleration and linear acceleration
(3) gravitational force and electromotive force
(4) none of these
22. The unit of measuring momentum per unit time of a moving body is: **[JSTSE 2016]**
(1) m sec^{-1} (2) kg m sec^{-1}
(3) newton (4) Nm^2 kg^{-2}
23. SI unit of Impulse is **[JSTSE 2017]**
(1) kg m/sec^2 (2) kg m/sec
(3) kg sec/m (4) newton-meter (Nm)

24. Momentum has same unit as that of - **[JSTSE 2018]**
(1) Impulse (2) Torque
(3) Moment of momentum (4) Couple

25. Which of the following pairs have not the same unit?
(1) friction force and upthrust
(2) force and weight
(3) weight and mass
(4) None of these



EXERCISE-2

1. Universal time is based on
(1) rotation of the earth on its axis
(2) earth's orbital motion around the Sun
(3) vibrations of cesium atom
(4) oscillations of quartz crystal

2. One yard in SI unit is equal to
(1) 1.9144 (2) 0.9144 (3) 0.09144 (4) 1.0936

3. 1° (degree) is equal to
(1) 17 radian
(2) 17.45×10^{-2} radian
(3) 17.45×10^{-5} radian
(4) 1.745×10^{-2} radian

4. One unified atomic mass unit is equal to
(1) 1.66×10^{-11} kg (2) 1.6×10^{-19} kg
(3) 1.67×10^{-27} kg (4) None of these

5. 1 Parsec is equal to
(1) 3.1×10^{-16} m (2) 3.26 ly
(3) 6.3×10^{4} Au (4) 1.496×10^{11} m

6. Unit of refrective index of a medium is
(1) m (2) kg
(3) N (4) unitless

7. Hz is the unit of
(1) angular velocity (2) angular acceleration
(3) frequency (4) time period

8. Ampere is the S.I. unit of
(1) potential difference (2) magnetic force
(3) electromotive force (4) electric current

9. S.I. unit of universal gravitational constant is
(1) $N-m^2/kg^2$ (2) N – m/s
(3) N/m^2 (4) $N-kg/m^2$

10. The wrong unit conversion among the following is
(1) 1 angstrom $= 10^{-10}$m
(2) 1 fermi $= 10^{-15}$m
(3) 1 light year $= 9.46 \times 10^{15}$m
(4) 1 astronomical unit $= 1.496 \times 10^{-11}$m

11. Consider the following statements and select the correct statement(s).
I. 1 calorie = 4.18 *joule*
II. $1\overset{o}{A} = 10^{-10}$ m
III. 1 MeV = 1.6×10^{-13} *joule*
IV. 1 newton = 10^{-5} *dyne*
(1) I, II and III (2) III and IV
(3) I only (4) IV only

12. Which is the unit of electromotive force?
(1) newton (2) dyne
(3) volt (4) None of these

13. SI unit of specific heat is
(1) J/kg–K (2) J– kg–K
(3) J–kg/K (4) None of these

14. Which is not the unit of energy?
(1) Joule (2) eV
(3) Calorie (4) Pascal

15. Energy equivalent to 12 watt hour is
(1) 43200 J (2) 58210 J
(3) 66320 J (4) 72 J

16. 76 mm of Hg is equivalent to
(1) 10^5 N/m^2 (2) 0.1 atm pressure
(3) 1 bar (4) None of these

17. Which of the following has larger length?
(1) 1 angstrom (2) 10^5 fermi
(3) 1 nanometre (4) 10^{-4} micron

18. Which of the following is heavier?
(1) 100 kg (2) 10^3 μg
(3) 10^3 mg (4) 10^6 ng

19. Unit of intensity level of sound is
(1) dB (2) MB
(3) GB (4) KB

20. Which of the following is/are correct?
I. Pressure = energy per unit area
II. Pressure = energy per unit volume
III. Pressure = force per unit volume
IV. Pressure = momentum per unit volume per unit time
(1) I and II (2) II only
(3) III only (4) I, II, III and IV

HINTS AND SOLUTIONS

Exercise 1

1. **(3)** 1 fermi = 10^{-15} metre

2. **(1)** SI is based on seven fundamental units.

3. **(2)** **4.** **(3)**

5. **(3)** 1 light year = speed of light in vacuum × no. of seconds in one year = $(3 \times 10^8) \times (365 \times 24 \times 60 \times 60)$ = 9.467×10^{15} m.

6. **(2)**

7. **(3)** $K = 273 + C \Rightarrow \Delta K = \Delta C$
i.e. the difference in temperature in °C = temperature difference in Kelvin scale.

8. **(4)** Parallactic second is the unit of distance.

9. **(3)**

10. **(2)** Vm^{-1} is the unit of electric field intensity.

11. **(3)** The bill of electric consumption is based on measurement of wattage.

12. **(4)** Relative density is ratio and ratio has no units.

13. **(2)**

14. **(1)** As force = change in momentum/time.
$\therefore$ force × time = change in momentum

15. **(3)** 1 pascal = 1 N / m^2.

16. **(3)** Electron volt is a unit of energy &
1eV = 1.6×10^{-19} joule

17. **(1)** Potential is work done per unit charge.

18. **(3)** $\frac{C}{5} = \frac{2C - 32}{9}$

$\Rightarrow C = 160\ ^oC$

19. **(3)** N kg^{-1} = force/mass = acceleration

20. **(3)**

21. **(1)** Both work and energy have same unit joule.

22. **(3)** Momentum per unit time is force and unit of force is Newton (N).

23. **(2)** Impulse = change in momentum = (Force × time)

24. **(1)**

25. **(3)** Friction force, gravitational force, buoyancy force, force, weight have same unit Newton or kg m/s^2. But mass is the fundamental physicl quantity having S.I. unit kg.

Exercise 2

1. **(3)** **2.** **(2)**

3. **(4)** **4.** **(3)**

5. **(2)** 1 parsec = 3.08×10^{16} m
1 ly = 9.46×10^{15} m

$\therefore \frac{1\text{Parsec}}{1\text{ly}} = \frac{30.8 \times 10^{15}}{9.46 \times 10^{15}} = 3.26$

$\therefore$ 1 Parsec = 3.26 ly

6. **(4)** Refractive index is a ratio of two similar physical quantity $\left(\mu = \frac{V_1}{V_2}\right)$. So, it is a unitless quantity.

7. **(3)** Hz (heartz) is the unit of frequency.

8. **(4)**

9. **(1)** $G = Fr^2/m_1m_2 = N\text{–}m^2/kg^2$

10. **(4)** 1 astronomical unit = 1.496×10^{11} m

11. **(1)** 1 newton = 10^5 *dyne*

12. **(3)** Electromotive force is not a force, its unit is volt (v).

13. **(1)**

14. **(4)** Pascal is the S.I. unit of pressure, while joule, eV, calorie are units of energy in different form.

15. **(1)** 12 watt hour = 12 × 3600 = 43200 joule

16. **(2)** 760 mm of Hg = 1 atm = 1 bar = 10^5 N/m^2
$\Rightarrow$ 76 mm of Hg = 0.1 atm pressure

17. **(3)** 1 A = 10^{-10} m; 10^5 fermi = $10^5 \times 10^{-15}$ m = 10^{-10} m; 1 nanometre = 10^{-9} m; 10^{-4} micron = $10^{-4} \times 10^{-6}$ m = 10^{-10} m.

18. **(1)** 100 kg = 100×10^3g = 10^5g, ; $10^3\mu g = 10^3 \times 10^{-6}$g = 10^{-3}g;
10^3 mg = $10^3 \times 10^{-3}$g = 1g; 10^6ng = $10^6 \times 10^{-9}$g = 10^{-3}g

19. **(1)** decibel (dB) is the unit of intensity level of sound

20. **(2)** Pressure = $\frac{\text{force}}{\text{area}} = \frac{\text{energy}}{\text{volume}} = ML^{-1}T^{-2}$